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Some Parameters Affecting the Quality of ESDA Results

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ABSTRACT: A systematic evaluation of the effect of humidity on ESDA images was made. The results showed that the quality of the ESDA images developed depends not upon the water content of the paper at the time the indentations are made, but rather on changes in the water content, which may occur during the period between the indentations being made and the paper being examined using the ESDA.

In order to study the effect of the moisture content on the quality of the image produced by the ESDA it was necessary to devise a system for producing standard impressions. This process has now found application as a quality control procedure for ESDA examination.

KEYWORDS: questioned documents, ESDA

The Electrostatic Detection Apparatus (ESDA) [*1*] has been used by Document Examiners all over the world to successfully develop and record indented impressions on paper documents, despite the fact that the actual mechanism by which the method works and the importance of some of the experimental conditions are still the subject of some conjecture [*1–7*].

Since its inception as an analytical tool for detecting indented impressions, there have been differing schools of thought as to the use of a humidifying chamber in the ESDA procedure.

The original paper by Foster and Morantz [*1*] made no mention of placing the document into a humidifying chamber prior to ESDA examination. Ellen [*2*] made no use of a humidifying chamber but suggested that failure (to produce an ESDA result) could be due to dryness of the paper, a problem that could be overcome by placing the document into a chamber containing a tray of water.

Noblett and James [*8*] exposed ten different types of paper to differing corona, toner development and relative humidity conditions to test the effects on ESDA results. They found that the average of the ten paper types tested produced the best ESDA results when exposed at 40% to 60% relative humidity for 15 min. Baier [*3*] placed documents into a "high humidity climatic chamber" for either 1 or 8 min to compare the quality of the ESDA detection process as a function of different technical and environmental

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factors. From this work, Baier concluded that high humidity contributed significantly to variance of the results.

The ESDA operating instructions [6] state that the major factor affecting the performance of the instrument is the moisture content of the document at the time of testing, and recommends that the documents be placed inside the humidifying chamber for 1 to 2 min before using the ESDA.

A number of questions emerge from this information. Should the humidifying chamber be used at all? What are the best conditions and times for a document to be placed into a humidifying chamber to give optimum ESDA results? What is the effect of differing climatic and laboratory conditions around the world? Does the water content of the paper at the time the indented impressions are being made influence the result? How important is the water content of the paper at the time the indented impressions are being made compared to the water content of the paper at the time of the ESDA examination?

This paper addresses some of these questions.

Experimental

Standard Indentations

In order to compare ESDA results under different conditions a technique for producing standardized impressions was devised.

The standard impressions were produced by affixing various weights (100, 200, 300, 400 and 500 g) to the end of a writing instrument. These weights simulate the varying pen pressures used by different individuals when writing. Without applying any additional downward pressure the weighted writing instrument was held between the fingers of the writing hand and moved across the surface of the top sheet of a stack of pages to produce a drawing.

Rating Scale

To quantify the ESDA results a rating scale for the developed impressions was used. The results were rated from 0 to 5 (Table 1) by evaluating the legibility (quality) of the result that was produced by the lightest pen pressure that was visible on each page of a stack.

Apparatus

Humidifying Chamber

Water was placed into a plastic tray fitted with a hinged lid and a metal grid platform on which the document was placed, suspending it above the water's surface. The humidifying chamber was placed inside a fume hood in a laboratory that was air-conditioned to 20°C.

Electrostatic Detection Apparatus

All imaging results were produced on an Electrostatic Detection Apparatus (ESDA) manufactured by Foster and Freeman Ltd, England, using the standard conditions (except

TABLE 1—*ESDA results rating scale for the developed impressions.*

Lightest pen pressure giving visible result	100g	200g	300g	400g	500g	not seen
Score	5	4	3	2	1	0

NOTE: If a result was visible but illegible, 0.5 was deducted from the score.

for humidifying times) and the Cascade Development method as set out in the Foster and Freeman Operating Instructions [6].

Paper Preparation

Three different types of commercially available A4 size paper[2] were used in the experiment.

The moisture content of the paper was adjusted to produce three different starting conditions as follows:

(i) Ambient conditions,
(ii) Minimum moisture content produced by drying the paper for 20 hours at 40°C in a laboratory oven,
(iii) Maximum moisture content produced by placing the paper in the humidifying chamber for 25 hours.

Preparation of Indented Impressions

For each of the three starting conditions three different types of paper were used. A series of nine stacks of paper six pages thick were made for each type of paper ($3 \times 3 \times 9 = 81$ stacks in total). A series of standard indented impressions (100 to 500 g) were then made on each of the eighty-one stacks. Pages 3, 4 and 5 in each stack was then examined by ESDA immediately after the standard impressions were made and the results were recorded.

ESDA Examination

For each of the 81 paper stacks the indentations on pages 3, 4 and 5 were developed by ESDA under the following conditions:

(i) Immediately after the indentations were made (T = To) "as indicated above,"
(ii) After the papers in (i) were dried for 20 hours at 40°C (T = T1). The purpose of this procedure was to reduce the water content of the paper to a base level from which the effect of humidification could be evaluated.
(iii) After the dried papers in (ii) were humidified for either 2, 4, 6, 8, 10, 12, 15, 20 or 30 minutes.

The results were recorded as a score out of 5 (Table 1).

Results

An evaluation of the ESDA results was made on pages 3, 4 and 5 from each of the 81 stacks of six pages thick. This evaluation is summarized in Figs. 1, 2, and 3 for commercially available lined paper (60 gsm). All of the other papers tested demonstrated similar results and trends when exposed to the same experimental conditions.

The Y-axis in each figure represents a score as defined in Table 1. Thus a graph of connected points is *not* of the *same* single sheet, but of the same depth-level sheet (third,

[2](i) Wesley Vale (Tasmania, Australia) white Bank paper of 45 grams per square meter (gsm) weight, calendared to 130–170 Sheffield units and 12% clay residue;
(ii) Wesley Vale Hi-form Bond paper of 60 gsm weight, machine calendared to 140–180 Sheffield units and 16% clay residue;
(iii) Wesley Vale Reflex of 80 gsm weight, calendared to 140 Sheffield units and 19% clay residue.

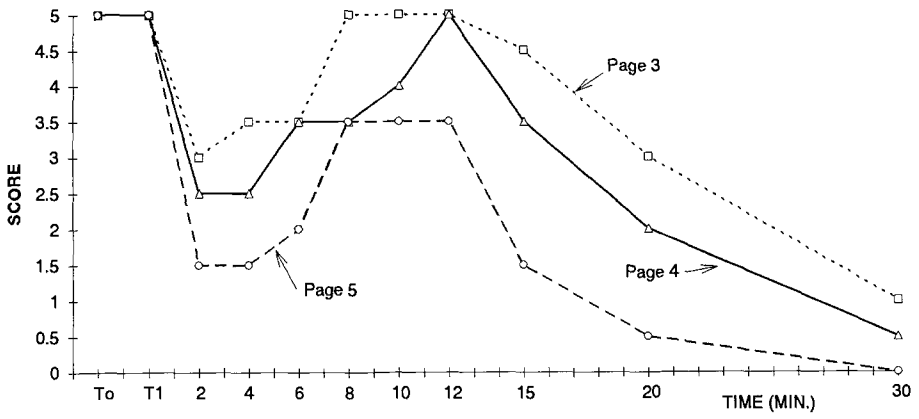

FIG. 1—*Minimum moisture content.*

fourth, or fifth) from those stacks and represents the lightest pen pressure that gave this sheet visible ESDA results.

Discussion

In general, the best results were obtained when the ESDA images were developed immediately after the indentations were made no matter what the initial moisture content of the paper (T = To, Figs. 1, 2, and 3).

Drying the paper indented under ambient conditions makes little difference to the result (see Fig. 2), probably because the moisture content was not greatly different to that of the dried paper. In contrast, the result for the paper indented under maximum moisture content (Fig. 3) was severely degraded when the paper was dried (especially pages 4 and 5). This was probably due to the significant changes in the paper structure under these conditions.

As the moisture content of the papers was restored by exposing them for different times in the humidifying chamber, the following general effects were observed:

(i) For the papers indented under ambient and minimum moisture content conditions, the quality of the ESDA results deteriorated with exposure times of up to about 6 min;

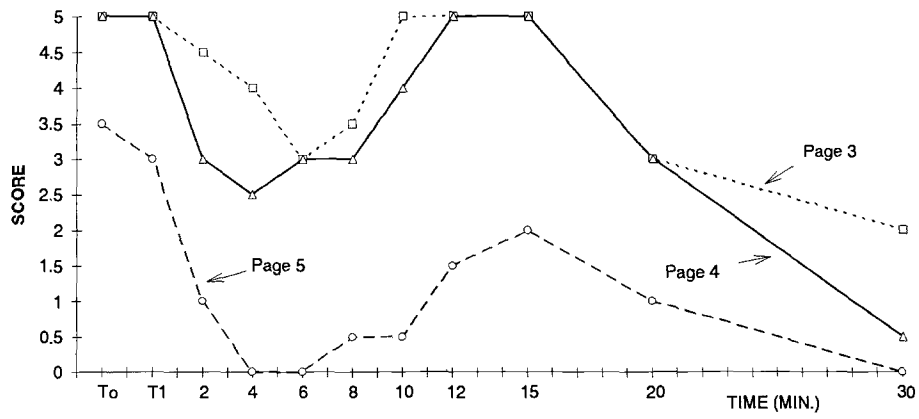

FIG. 2—*Ambient conditions.*

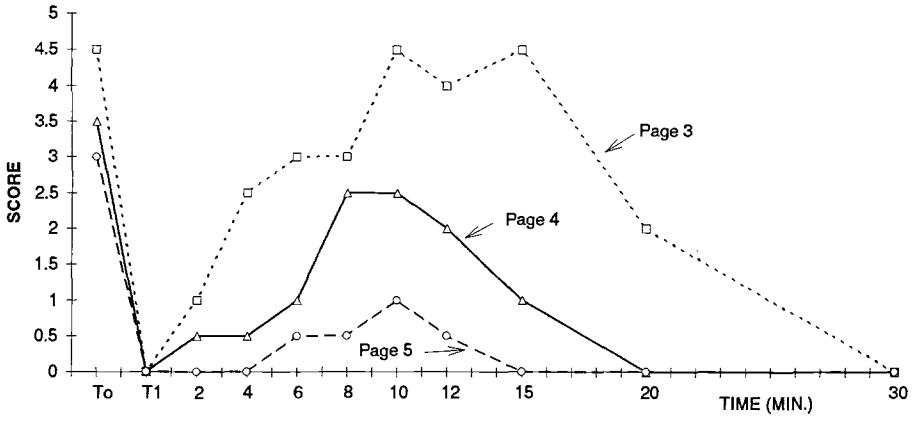

FIG. 3—*Maximum moisture content.*

(ii) For the paper that was indented with maximum moisture content the degradation of the result by drying was reversed by humidification, with recovery improving through the first 6 min of exposure;

(iii) For all papers, significant recovery in the quality of the results occurred after exposure times of between 8 and 15 min;

(iv) Exposures longer than 15 min tended to produce a deterioration in the result once more.

It should be noted that these experiments have been carried out in a laboratory environment at 20°C in a location that is of Mediterranean climatic conditions (Adelaide, Australia) and that the humidification conditions to give the optimum ESDA results may vary with a change in laboratory or climatic conditions. Therefore curves similar to those produced in this study should be determined for different operational environments.

Conclusion

The best quality ESDA result was obtained at the time the indentations were made (T = To) with no alteration to the condition of the paper.

Changes in the water content of the paper which occur after the indentations are made, but before the paper is examined using the ESDA, have a more significant influence on the quality of the ESDA result than the condition of the paper at the time the indentation is made.

The results show the time for optimum exposure in the humidifier when working with paper which has been completely dried. In casework situations the initial moisture content of the paper is unknown, so how it would rate on the scoring curves is not known either. Thus if humidification is used the main problem will be achieving the optimum time and avoiding overexposure.

The following procedures were found to provide optimum ESDA results in our laboratory and may serve as a guide to ESDA operators in establishing the ideal parameters in their own environment:

(i) Pages with suspected indented impressions should be firstly examined by the ESDA without using the humidifying chamber as humidification may cause a degradation of the result;

(ii) If unsuccessful, the paper should be placed into the humidifying chamber for 8 to 15 min to recover from any effects of drying;

(iii) Indented paper overexposed to water vapor (T > 15 min in humidifier) will give less than optimum ESDA results. The indented paper, when slowly dried to reduce its water content, may produce better quality results;

(iv) The higher the page is in the original stack, the better the quality of the ESDA which can be achieved when the paper is re-humidified.

Quality Assurance

The method used to create the standard impressions has been useful as a quality control procedure for ESDA examination. Standard ESDA impressions can be measured routinely, thereby alerting the operator to any changed conditions that may affect the result.

The production of the series of standardized indented impressions allows:

(i) the monitoring of the day-to-day results from the ESDA,

(ii) the evaluation of operator proficiency for training purposes,

(iii) the evaluation of the importance of the water content of paper in giving optimum ESDA results.

One of the pages bearing the standardized indented impressions is now routinely tested as a quality assurance sample before commencing every case requiring ESDA examination. Furthermore, the standardized impressions are used for monitoring seasonal variation in the conditions required to produce optimum ESDA results.

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